AD NUMBER

AD013310

CLASSIFICATION CHANGES

TO: unclassified

FROM: confidential

LIMITATION CHANGES

TO:

Approved for public release, distribution unlimited

FROM:

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational use; Apr 1953. Other requests shall be referred to Armed Forces Special Weapons Project, Washington DC.

AUTHORITY

Apr 1965, DoDD 5200.10, 26 July 1962; DNA ltr, 15 Mar 1977

AD _____

AFSWP-382

13 APR 1953

SECURITY INFORMATION

Lab. Project 5046-3, Part 30
Final Report
NS 081-001
NS 068-001

MATERIAL LABORATORY
NEW YORK NAVAL SHIPYARD
BROOKLYN 1, N. Y.

TECHNICAL REPORT

3ND-NYNS-900-P-1

MEASUREMENTS OF DEPTH OF CHAR ON WOODS EXPOSED TO HIGH-INTENSITY THERMAL RADIATION

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H. Korbel

Lab. Project 5046-3, Part 30
Final Report
NS 081-001
NS 088-001

Technical Objectives AW-7, SR-2A
AFSWP-382
13 April 1953

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ABSTRACT

Protective coatings on woods were tested for their efficacy against high-intensity thermal radiation, using depth of char as the criterion of damage to the wood. This method was found to be reliable, when the limitation of the nonuniformity of wood was overcome by taking a large number of readings. Field and laboratory results agreed with each other within the limits of accuracy prescribed by the small number of field samples.

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Ref: (a) COMNYKNAVSHIPYD ltr C-S99/L5, Ser 960-92, of 15 Mar 1950
(b) BUSHIPS restr spdltr S99-(0)(348), Ser 348-75, of 6 Apr 1950

Encl: (1) Depth of Char versus Radiant Exposure, Coated White Pine Exposed to Carbon-arc Source at 85 cal/cm^{2}sec
(2) Depth of Char versus Radiant Exposure, Coated Maple Exposed to Carbon-arc Source at 85 cal/cm^{2}sec
(3) Depth of Char of Coated Woods Exposed to Carbon-arc Source for 0.46 sec at 85 cal/cm^{2}sec
(4) Depth of Char of Field Samples
(5) Equivalent Laboratory Exposures of Field Samples of Coated Woods

AUTHORITY

1. This investigation is part of the program proposed by reference (a) and formally approved by reference (b). The general Thermal Radiation program is under the supervision of the Armed Forces Special Weapons Project.

INTRODUCTION

2. The Naval Material Laboratory exposed a number of coated wood samples at Operation BUSTER, to determine which coating types offer the most protection to wood against high-intensity thermal radiation. In order to evaluate the effectiveness of each coating a means of measuring the damage incurred by the protected wood specimen obviously is required. The method of measuring should give quantitative results which are indeed a measure of damage; i.e., for wood used in structures, how much the wood is weakened by the radiation, and to what extent it tends to start to burn or cause nearby flammable materials to burn.

3. In order not to delay NML's report on Operation BUSTER, a simple visual method of assaying damage was employed and reported therein[1], with the statement that the results would be further studied by measurement of depth of char. The present report gives the results of the depth-of-char measurements.

4. The depth-of-char measurement is a simple and objective method which would be expected to meet the requirement of paragraph 2. The depth to which the wood has been charred should indicate the amount of weakening and also the amount of flame-producing volatile material which has been driven off by the radiation.

[1] Refers to Bibliography

5. The objectives of this investigation were to use the depth-of-char method to determine which protective methods are most effective, and to compare the results of laboratory and field exposures of wood specimens. The finding of agreement between laboratory and field results would establish the reliability of depth-of-char measurements, and would further establish the validity of the present laboratory thermal-radiation exposure technique.

PREPARATION AND EXPOSURE OF SAMPLES

6. For the field test, at Operation BUSTER, maple and white pine specimens, 1-3/4x3-7/16x1/4 in., were carefully planed to obtain parallel faces. The wood was prepared for the protective coating by applying two coats of lacquer sealer and rubbing with fine steel wool. A film of the protective paint, of 0.005-in. wet thickness, was carefully applied with a film applicator. The specimens were then allowed to dry. The paints used were: Albi Temp Kote 99 (Albi Mfg. Co., Hartford, Conn.), Vita-Var Exterior 20 (Vita-Var Corp., Newark, N.J.), Glyptol 2527 (G.E.), Federal Specification TT-E-489 and TT-E-485b paints, and an olive-drab low-infrared-reflecting paint. The first two were light-gray commercial fire-retardants; the first operates by intumescing when heated, the second is loaded with non-bombustibles. The remaining paints were olive drab; the third has a high infrared reflectance, the fourth absorbs heat by an endothermic reaction, and the fifth has a somewhat lower infrared reflectance than the third.

7. The field samples were clamped to the exposure panels by metal straps which left a 1-3/4x2-1/2 in. area exposed. At most, one sample of each type was exposed at each field station.

8. The samples for the laboratory exposures were prepared in the same way. These samples were 8x1x1/4 in. in size, so that they could be exposed by the moving-strip method. In this method, the samples are moved with steadily increasing speed through the focus of the carbon-arc radiation source, so that the radiant exposure decreases continuously along the length of the sample. The irradiance remains constant at 85 cal/cm^{2}sec.

MEASUREMENT OF DAMAGE

9. Damage was evaluated by measuring how deep below the exposed wood surface the wood had become black in color. To measure this depth, the specimen was sectioned, and the cross section was viewed through a 10-power microscope. The line of demarcation between charred and uncharred wood was quite sharp when viewed in this manner. The depth of char was measured by moving the microscope hair line, by means of the micrometer mount, from the surface of the wood to the point of deepest char. Inasmuch as the original, exposed surface of the wood sample had been destroyed by the exposure, the plane of this surface was defined by a glass plate clamped to the undamaged bare wood surface at the edge of the sample. For the painted specimens, this necessitated scraping off the paint with a razor blade.

10. The field samples were sectioned into four (4) rectangles by two (2) orthogonal cuts through the center. Twenty-four depth-of-char readings were taken on each sample. The laboratory samples were sectioned and measured at regular intervals along the length. This permitted a study of the depth of char as a function of radiant exposure for each type of sample.

RESULTS

11. The curves relating depth of char and radiant exposure in the laboratory for maple and white pine, unprotected and with 3 different coatings, are given in Enclosures (1) and (2). The depth is seen to be roughly proportional to the radiant exposure for the unprotected and merely lacquered woods; at the lowest exposures, however, the lacquered samples show greater damage, because of ignition of the lacquer by the radiation. The woods which were protected by Albi Temp Kote 99 or Vita-Var Exterior 20 showed considerably less damage at each exposure than the unprotected woods, and the damage increased more slowly with respect to exposure.

12. All of the coatings used were compared by measuring the depth of char at the arbitrary exposure of 40 cal/cm^2. The results are shown in Enclosure (3). Albi Temp Kote 99, Vita-Var Exterior 20, and Glyptol 2527 are seen to give considerable protection to the woods.

13. The results of the measurements on the field samples are given in Enclosure (4). Vita-Var Exterior 20 is shown to offer the most protection, although Albi Temp Kote 99 and Glyotol 2527 were also effective. No completely uncoated specimens were exposed in the field; samples with lacquer sealer only were used as the controls.

14. Because of inhomogeneity of the wood, the depth of char was not constant along any one cross section. Grain was the most obvious cause of nonuniformity; when a section ran along a single grain, the particular depth of that section would improperly weight the average depth for the sample. These factors led to scatter among the individual readings for a single sample, and among nominally equal samples. Individual readings at different points of a single specimen differed as much as 100 per cent from each other. Similar specimens given equal exposures in the laboratory differed by as much as 25 per cent from each other. The same specimen, measured twice, would yield consistent results within 5 per cent.

COMPARISON OF FIELD AND LABORATORY RESULTS

15. In order to obtain a sensitive and directly meaningful comparison of field and laboratory results, the following method was used. The depth of char of each field sample was applied to the corresponding laboratory curve, such as those of Enclosures (1) and (2), to obtain an equivalent laboratory radiant exposure. If the equivalent laboratory radiant exposure was found to be equal to the radiant exposure to which the sample was known to have been subjected in the field, then the field-laboratory correlation would be considered perfect in this case. Enclosure (5) shows the results of this comparison for all of the BUSTER samples which showed a measurable depth of char. A second column is presented to show the results of a similar comparison which used the visual appearance of the field-and-laboratory-exposed samples, instead of depth-of-char. It is to be noted that the depth-of-char technique yields a higher correlation than the visual technique. In view of the results of the laboratory measurements on reliability of results for a single specimen, a higher correlation would be expected if duplicate specimens could have been exposed in the field.

CONCLUSIONS

16. The adequate correlation of field and laboratory results indicates that depth-of-char measurement is a reliable method for assaying damage to flat wood specimens, and that the laboratory exposure method is valid as a means of predicting field results. Because of the inhomogeneity of wood, there is nonuniformity within a sample and from sample to sample, and so the reliability increases with the number of measurements and samples.

17. The validity of depth of char as a useful definition of damage in woods has not been established experimentally, but it certainly may be conjectured to indicate the amount of structural weakening when the wood is deeply charred, and amount of flammable material evolved.

18. According to the present results, Albi Temp Kote 99, Vita-Var 20, and Glyptol 2527 afford considerable protection to wood. Part of this protection is probably due to the higher reflectance of the first two, which are light gray in color; Glyptol 2527, however, was olive drab, as were all the other paints tested.

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Approved:

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The Director

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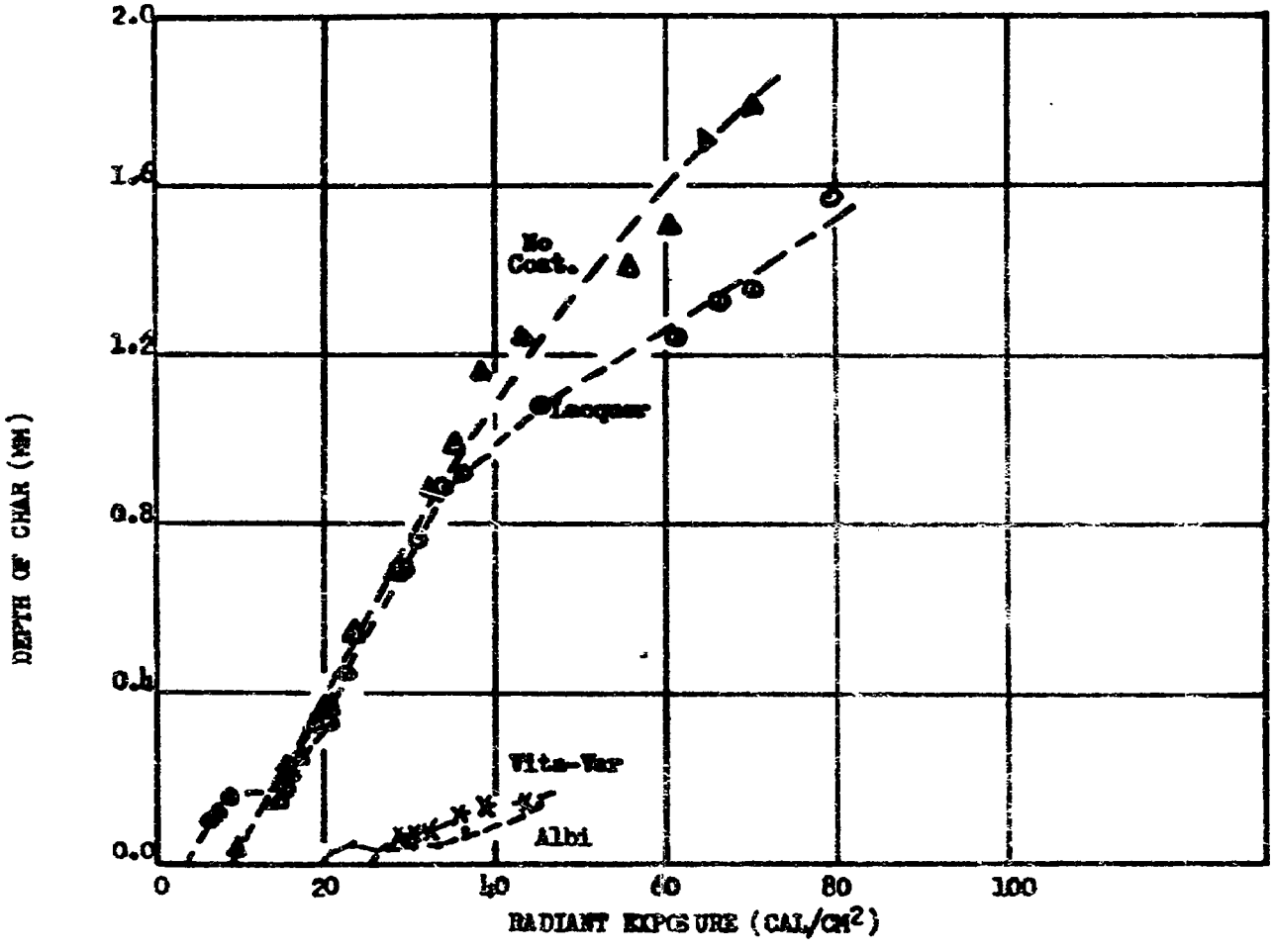
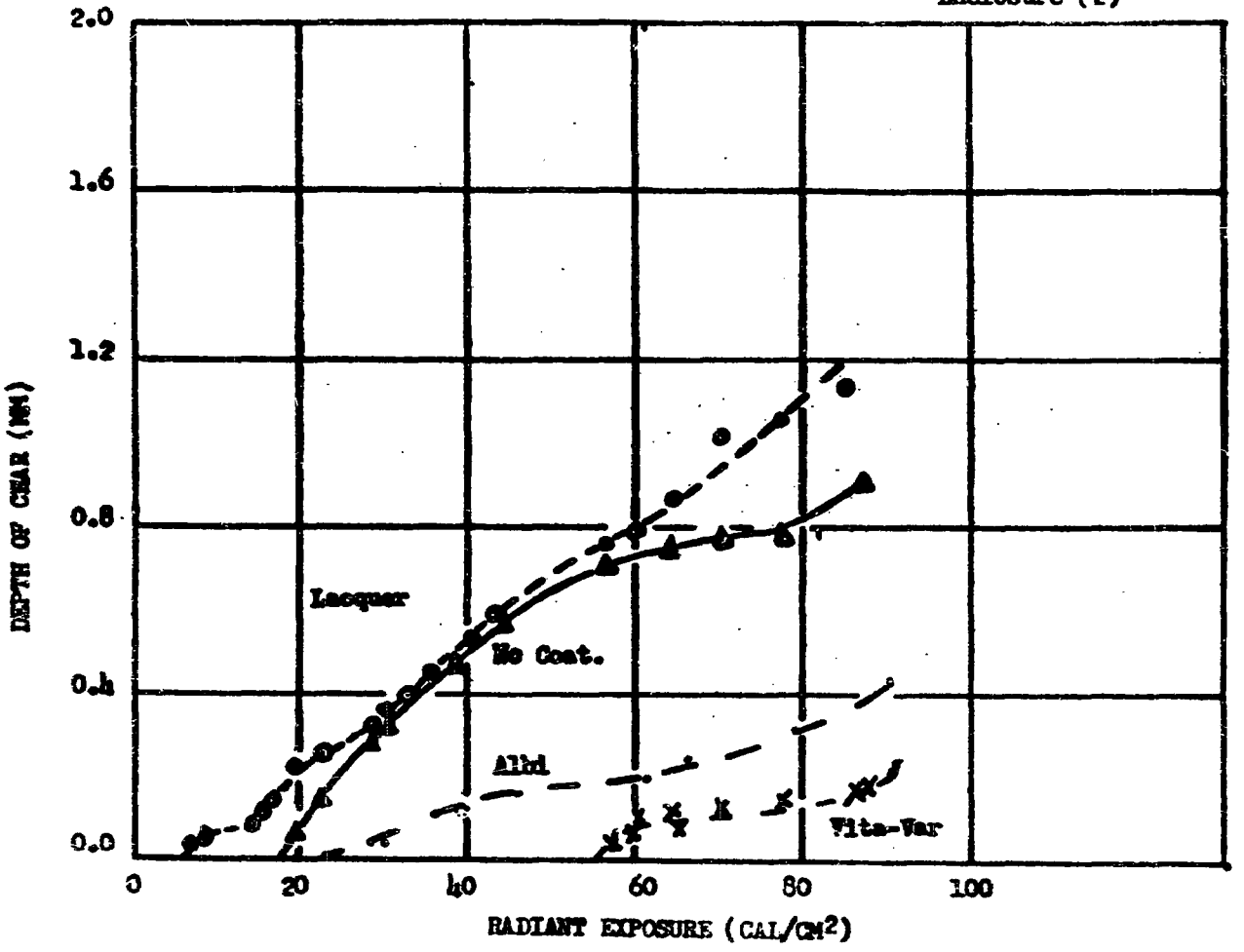


Depth of Char versus Radiant Exposure - Coated White Pine Exposed to Carbon-arc Source at 85 cal/cm²sec



Depth of Char versus Radiant Exposure. Coated Maple Exposed to Carbonarc Source at 85 cal/cm^{2}sec

Depth of Char of Coated Woods
Exposed to Carbon-arc Source for 0.46 sec at 85 cal/cm^{2}sec

Paint System	Wood	Depth of Char (mm)
Albi Temp Kote 99	White Pine	0.06
Vita-Var Ext. 20	White Pine	0.11
Glyptol 2527	White Pine	0.42
Low IR Refl.	White Pine	0.75
Lacquer	White Pine	1.00
Unprotected	White Pine	1.18
TT-E-489	White Pine	--[1]
Vita-Var Ext. 20	Maple	--[2]
Glyptol 2527	Maple	0.11
Albi Temp Kote 99	Maple	0.12
TT-E-485b	Maple	0.22
Unprotected	Maple	0.51
Lacquer	Maple	0.52

1 Insufficient data

2 Initial effect occurs at 54 cal/cm^2

Depth of Char of Field Samples

Shot	Exposure* (cal/cm^2)	Paint System	Wood	Depth-of-Char (mm)
Baker	17	Vita-Var Ext. 20	W. Pine	0.00
		Glyptol 2527		0.00
		TT-E-489		0.08
		Albi Temp Kote 99		0.11
		Low IR O.D.		0.11
		Lacquer only		0.11
		Vita-Var Ext. 20	Maple	0.00
		Glyptol 2527		0.00
		TT-E-485b		0.00
		Albi Temp Kote 99		0.00
		Lacquer only		0.00
Dog	21	Vita-Var Ext. 20	W. Pine	0.00
		Albi Temp Kote 99		0.00
		Glyptol 2527		0.08
		TT-E-489		0.18
		Low IR O.D.		0.32
		Lacquer only		0.38
		Vita-Var Ext. 20	Maple	0.00
		Albi Temp Kote 99		0.09
		Glyptol 2527		0.09
		TT-E-485b		0.09
		Lacquer only		0.27
Dog	14	Vita-Var Ext. 20	W. Pine	0.00
		Albi Temp Kote 99		0.00
		Lacquer only		0.02
		Low IR O.D.		0.07
		TT-E-489		0.08
		Glyptol 2527		0.11
		Vita-Var Ext. 20	Maple	0.00
		Albi Temp Kote 99		0.00
		Glyptol 2527		0.00
		TT-E-485b		0.00
		Lacquer only		0.01

* From NML foil data.

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Equivalent Laboratory Exposures of Field Samples of Coated Woods

Shot	Field Exposure (cal/cm^2) from			Sample	Equiv. Lab. Exposures (cal/cm^2) from	
	NRDL Foils	NRDL Calor	NML Foils		Depth of Char	Visual Exam.
Baker	19.6	--	16.9	Lacquer, wh. pine	7	56
				Albi T. Kote, wh. pine	43	18
				Low IR Refl. O.D., wh. pine	24	27
				TT-E-489, wh. pine	16	15-27
				Average	22	30
Dog	24.2	35.5	21.2	Lacquer, wh. pine	21	60
				Lacquer, maple	24	33
				Albi T. Kote, maple	29	47
				Glyptol, wh. pine	21	28
				Glyptol, maple	32	27
				Low IR Refl. O.D., wh. pine	29	49
				TT-E-489, wh. pine	17	27
				TT-E-485b, maple	32	27-43
				Average	26	38
Dog	15.5	17.5	14.2	Lacquer, wh. pine	12	48
				Lacquer, maple	14	15
				Glyptol, wh. pine	22	31
				TT-E-489, wh. pine	14	17
				Average	15	28